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(54) [Title of the Invention]
Fine Pattern Forming Device and Method
(57) [Abstract]
[Problem to be Solved] To provide a fine pattern forming device that can form a fine

pattern with high accuracy by drawing it directly with ink, and a fine pattern forming method whose process is simple.

[Means for Solving the Problem] A fine pattern forming device is made so as to comprise a silicon substrate having a plurality of fine holes provided to penetrate from the front surface to the rear surface, a support member placed on the front surface side of the silicon substrate, an ink path for supplying ink to openings of the fine holes on the silicon substrate front surface side, and an ink supply unit connected to the ink path. Scanning the fine pattern forming device and a substance on which the pattern is formed relatively in a predetermined direction, the ink supplied from the ink path is discharged continuously, through each fine hole, on the substance on which the pattern is formed so that a striped pattern is formed. In addition, the above-described fine pattern forming device is placed in a predetermined position of a substance on which a pattern is formed and a certain amount of ink supplied from the ink path is discharged, through each fine hole, on the substance on which the pattern is formed, so that the pattern is formed.

[Scope of Claims]

[Claim 1] A fine pattern forming device comprising:

a silicon substrate;

a plurality of fine holes provided so as to penetrate from a front surface to a rear surface of the silicon substrate;

a support member placed on a front surface side of the silicon substrate;

an ink path for supplying ink to openings of the fine holes on the silicon substrate front surface side; and

an ink supply unit connected to the ink path.

[Claim 2] A fine pattern forming device according to claim 1, wherein a nozzle is provided in a protruding condition on the opening of the fine hole on the silicon substrate rear surface side.

[Claim 3] A fine pattern forming device according to claim 2, wherein a wall surface of the fine hole has a silicon oxide layer, and the nozzle is formed of silicon oxide.

[Claim 4] A fine pattern forming device according to any one of claim 1 to claim 3, wherein opening diameters of the fine holes are in a range of 1 to 100 μm, and forming pitches of the fine holes are in a range of 1 to 1000 μm.

[Claim 5] A fine pattern forming device according to any one of claim 1 to claim 4, wherein a linear expansion coefficient of the support member is in a range of 1/10 times to 10 times of a linear expansion coefficient of the silicon substrate.

[Claim 6] A fine pattern forming device according to any one of claim 1 to claim 5, wherein a shape of a transverse section which is vertical to an axial direction of the fine

hole is one kind of or more than one kinds of a circular form, an elliptical form and a polygon.

[Claim 7] A fine pattern forming device according to any one of claim 1 to claim 6, wherein a shape of a longitudinal section along the axial direction of the fine hole is a rectangle or a trapezoid whose silicon substrate rear surface side is narrow.

[Claim 8] A fine pattern forming device according to any one of claim 1 to claim 7, wherein the fine holes are divided into two or more groups, and each fine hole group is provided with a distinct ink path.

[Claim 9] A method for forming a fine pattern wherein a striped pattern is formed by continuously discharging ink which is supplied from an ink path, through each fine hole, on a substance on which the pattern is formed, while scanning a fine pattern forming device according to any one of claim 1 to claim 8 and the substance on which the pattern is formed relatively in a predetermined direction.

[Claim 10] A method for forming a fine pattern according to claim 9, wherein each constituent stripe of a pattern is formed by supplying ink from a plurality of fine holes placed on the same line along the scanning direction.

[Claim 11] A method for forming a fine pattern, wherein a fine pattern forming device according to any one of claim 1 to claim 8 is placed in a predetermined position of a substance on which a pattern is formed and a certain amount of ink supplied from the ink path is discharged, through each fine hole, on the substance on which the pattern is formed, so that the pattern is formed.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to a fine pattern forming device and a fine pattern forming method using this device, especially a fine pattern forming device and method which can be applied to pattern formation in manufacturing a flat display such as a liquid crystal display and a plasma display, conductor pattern formation of a printed-wiring board or the like.

[0002]

[Prior Art] For example, formation of a fine pattern such as a color filter for a liquid crystal display is performed by photolithography, printing, electrodeposition or the like. Of these forming methods, photolithography is superior in accuracy and appearance quality. In addition, photolithography capable of highly accurate wiring is also used for formation of a conductor pattern of a printed-wiring board.

[0003] In an example of manufacturing a color filter by photolithography, a photosensitive resist is applied to a metal thin film such as chrome formed by sputtering

or evaporation, a resist pattern is formed by exposure through a photomask and development, and the metal thin film is etched using this as a mask to be patterned, so that a black matrix is formed. Next, after a photosensitive resist containing a coloring pigment is applied, exposure through a photomask and development are performed, so that a colored layer of the color filter is formed. On the other hand, as for a printed-wiring board, a pattern of a photosensitive resist is formed on a copper plating layer, and the copper plating layer is etched using the resist as a mask, so that a conductor pattern is manufactured.

[0004]

[Problems to be Solved by the Invention] However, the processes of pattern formation of a color filter and conductor pattern formation using the above-described photolithography are complicated, and it has been an obstacle to the reduction of manufacturing cost.

[0005] The present invention is made in view of the above-described circumstances, and the object is to provide a fine pattern forming device that can form a fine pattern with high accuracy by drawing it directly with ink, and a fine pattern forming method whose process is simple.

[0006]

[Means for Solving the Problems] In order to achieve such object, a fine pattern forming device of the invention is structured to comprise a silicon substrate, a plurality of fine holes provided so as to penetrate from a front surface to a rear surface of the silicon substrate, a support member placed on a front surface side of the silicon substrate, an ink path for supplying ink to openings of the fine holes on the silicon substrate front surface side, and an ink supply unit connected to the ink path.

[0007] Furthermore, a fine pattern forming device of the invention is structured to have a nozzle provided in a protruding condition on the opening of the fine hole on the silicon substrate rear surface side.

[0008] Furthermore, a fine pattern forming device of the invention is structured so that a wall surface of the fine hole has a silicon oxide layer, and the nozzle is formed of silicon oxide.

[0009] Furthermore, a fine pattern forming device of the invention is structured so that opening diameters of the fine holes are in a range of 1 to 100 μm, and forming pitches of the fine holes are in a range of 1 to 1000 μm.

[0010] Furthermore, a fine pattern forming device of the invention is structured so that a linear expansion coefficient of the support member is in a range of 1/10 times to 10 times of a linear expansion coefficient of the silicon substrate.

[0011] Furthermore, a fine pattern forming device of the invention is structured so that a shape of a transverse section which is vertical to an axial direction of the fine hole is one kind of or more than one kinds of a circular form, an elliptical form and a polygon.

[0012] Furthermore, a fine pattern forming device of the invention is structured so that a shape of a longitudinal section along the axial direction of the fine hole is a rectangle or a trapezoid whose silicon substrate rear surface side is narrow.

[0013] Furthermore, a fine pattern forming device of the invention is structured so that the fine holes are divided into two or more groups, and each fine hole group is provided with a distinct ink path.

[0014] A method for forming a fine pattern of the invention is structured so that a striped pattern is formed by continuously discharging ink which is supplied from an ink path, through each fine hole, on a substance on which the pattern is formed, while scanning a fine pattern forming device described above and the substance on which the pattern is formed relatively in a predetermined direction.

[0015] Furthermore, it is structured so that each constituent stripe of a pattern is formed by supplying ink from a plurality of fine holes placed on the same line along the scanning direction.

[0016] Furthermore, a method for forming a fine pattern of the invention is structured so that a fine pattern forming device described above is placed in a predetermined position of a substance on which a pattern is formed and a certain amount of ink supplied from the ink path is discharged, through each fine hole, on the substance on which the pattern is formed, so that the pattern is formed.

[0017] With the invention as this, the ink discharged from the fine holes of the silicon substrate is attached on the substance on which the pattern is formed and direct drawing is performed, and the amount of ink attached can be changed arbitrarily, by changing the amount of ink supply.

[0018]

[Embodiment modes] Hereinafter, embodiment modes of the invention will be described, referring to drawings.

[0019] Fine Pattern Forming Device

(First embodiment mode) Fig. 1 is a schematic cross-sectional view showing an embodiment mode of a fine pattern forming device of the invention. In Fig. 1, a fine pattern forming device 1 is provided with a silicon substrate 2, a support member 6 which is placed on a front surface 2A side of the silicon substrate 2, an ink path 8 which supplies ink to a void part between the silicon substrate 2 and the support member 6, and an ink supply unit 9 connected to the ink path 8.

[0020] The silicon substrate 2 is provided with a plurality of fine holes 3 which penetrate from the front surface 2A side to a rear surface 2B side, and openings 3a on the front surface 2A side of the fine holes 3 are exposed to a void part formed by the above-described silicon substrate 2 and the support member 6. A material of the silicon substrate 2 is preferably single crystal of silicon, and the thickness is preferably approximately 200 to 500 μm. Since its linear expansion coefficient is as low as approximately 2.6×10^{-6}/K, thermal formation change of the silicon substrate 2 as this is extremely small.

[0021] The fine hole 3 is a cylinder-shaped space whose transverse section shape (the cross-section parallel to the front surface 2A of the silicon substrate 2) which is vertical to the axial direction is a circular form and whose longitudinal section shape (the cross-section vertical to the front surface 2A of the silicon substrate 2) along the axial direction is a rectangle, and the wall surface is provided with a silicon oxide layer 4. Usually, a thickness of the silicon oxide layer 4 is approximately 5000 to 10000 Å. Although an opening diameter, the formation number, a forming pitch and the like of the fine holes 3 provided with the oxide layers 4 are simplified to describe the structure of the device in the example shown in the figure, the opening diameter of the fine hole 3 can be set to be approximately 1 to 100 μm, and the aspect ratio of the fine hole 3 can be set in a range of 1 to 100, arbitrarily. In addition, the formation number and forming pitch of the fine holes 3 may be set arbitrarily according to the form, the forming method or the like of the pattern formed by the fine pattern forming device 1, and it is preferable that the forming pitch is approximately 1 μm at minimum.

[0022] The transverse section shape of the fine hole 3 may be an elliptical form, a polygon, or a particular form, besides a circular form described above. Furthermore, the fine holes 3 may be two or more kinds of fine holes having different transverse section shapes. In the case where the transverse section shape is an elliptical form or a rectangle, the diameter of the longitudinal direction can be set arbitrarily in a range of 5 to 500 μm. In addition, the longitudinal section shape of the fine hole 3 may be a trapezoid whose silicon substrate 2 rear surface 2B side is narrow (a taper form), besides a rectangle described above.

[0023] The support member 6 is placed on the front surface 2A side of the above-described silicon substrate 2, for holding the silicon substrate 2. In the example shown in the figure, the support member 6 is structured by a base 6a with a planar shape in the same way as the silicon substrate 2, a flange part 6b provided on the periphery of the base 6a and an opening 6c provided on the center of the base 6a, and it is bonded to the peripheral part of the silicon substrate 2 front surface 2A side at the flange part 6b.

By this, a space where ink is supplied is formed between the silicon substrate 2 and the support member 6. For the support member 6, it is preferable that a material whose linear expansion coefficient is in a range of 1/10 times to 10 times of a linear expansion coefficient of the silicon substrate 2 is used. For example, pyrex glass (trade name Corning #7740, linear expansion coefficient = 3.5×10^{-6}/K), SUS304 (linear expansion coefficient = 17.3×10^{-6}/K) or the like may be used. By this, a strain generated by heat between the silicon substrate 2 and the support member 6 is extremely small, flatness of the silicon substrate 2 is maintained, and pattern formation with high accuracy is possible.

[0024] The ink path 8 is connected to the opening 6c of the above-described support member 6, and the other end is connected to an ink supply unit 9. Although one pipe-shaped ink path 8 is connected in the example shown in the figure, a plurality of openings 6c may be provided and the ink path 8 may be connected to each of the openings 6c, considering the size of the fine pattern forming device 1, the uniformity of fluid pressure of the ink and the like. Furthermore, by processing the support member 6 and the silicon substrate 2, the ink path may be formed inside the support member 6 and/or the silicon substrate 2.

[0025] The ink supply unit 9 has no special limitation, and it may be any of a continuous supply pomp, a constant rate supply pomp and the like, selected arbitrarily according to the intended use of the fine pattern forming device 1.

[0026] Such fine pattern forming device 1 of the invention can discharge ink in a small amount with high accuracy from the fine holes 3 of the silicon substrate 2. In addition, the amount of ink discharged can be set arbitrarily by changing the supplying amount by controlling the ink supply unit 9. Therefore, a highly accurate pattern can be formed stably on a substance on which the pattern is formed, by direct drawing.

[0027] (Second embodiment mode) Fig. 2 is a schematic cross-section view showing another embodiment mode of a fine pattern forming device of the invention. As shown in Fig. 2, the basic structure of a fine pattern forming device 1' is the same as the above-described fine pattern forming device 1, and nozzles 5 are provided in a protruding condition on the openings 3b of the fine holes 3 on the silicon substrate 2 rear surface 2B side of the fine pattern forming device 1'. The nozzle 5 is formed of silicon oxide, and formed integrated with the above-described silicon oxide layer 4. The protruding amount can be set arbitrarily in a range of 0 to 100 μm. By providing such nozzles 5, the ink discharged from the fine holes 3 is prevented from attaching to the silicon substrate 2 rear surface 2B side.

[0028] (Third embodiment mode) Fig. 3 is a schematic cross-section view showing

another embodiment mode of a fine pattern forming device of the invention, and Fig. 4 is a bottom view of the fine pattern forming device shown in Fig. 3. In Fig. 3 and Fig. 4, a fine pattern forming device 11 is formed by continuous three device parts 11a, 11b and 11C, and provided with a common silicon substrate 12, three support members 16 placed on a front surface 12A side of the silicon substrate 12, three ink paths 18 which supply ink to void parts between the silicon substrate 12 and each of the support members 16, and ink supply units 19a, 19b and 19c connected to these ink paths 18.

[0029] The silicon substrate 12 has a plurality of fine holes 13 penetrating from the front surface 12A side to a rear surface 12B side per each device part 11a, 11b and 11c, and openings 13a on the front surface 12A side of the fine holes 13 are exposed to each void part formed by the silicon substrate 12 and each support member 16. A material of the silicon substrate 12 can be the same as the above-described silicon substrate 2, and the thickness can be also set in the same range as the silicon substrate 2.

[0030] The fine holes 13 are formed with a pattern where a plurality of them are placed on the same lines along a predetermined direction (an arrow A direction in Fig. 4) per each device part 11a, 11b and 11c. That is, a plurality of lines of fine holes 13 placed along the arrow A direction are formed in the device part 11a with a pitch P1, and a plurality of lines of the fine holes 13 are formed in the device part 11b and the device part 11c with the pitch P1 in the same way as this. Since the lines of fine holes 13 in each device part 11a, 11b and 11c have different alignments from each other with the pitch P2 (P1 = 3×P2), the fine pattern forming device 11 as a whole has fine hole lines of each device part 11a, 11b and 11c, aligned repeatedly with the pitch 2. The transverse section shape, longitudinal section shape, opening diameter and forming pitch of the fine holes 13 as these can be set arbitrarily, in the same way as the above-described fine holes 3. In addition, a silicon oxide layer 14 formed on the wall surface of the fine hole 13 can be the same as the above-described silicon oxide layer 4. In the example shown in the figure, the opening diameter, formation number, forming pitch and the like of the fine holes 13 provided with the silicon oxide layers 14 are simplified so that the description of the device structure becomes easier.

[0031] The support members 16 are placed on the front surface 12A side of the above-described silicon substrate 12, for holding the silicon substrate 12. In the example shown in the figure, the support member 16 is formed of a base 16a with a planar shape in the same way as the silicon substrate 12, a flange part 16b provided on the periphery of the base 16a and an opening 16c provided on the center of the base 16a, and it is bonded to the front surface 12A side of the silicon substrate 12 at the flange part 16b, in the same way as the above-described support member 6. By this, a void

where ink is supplied is formed between the silicon substrate 12 and each support member 16. The material of the support member 16 is preferably a material whose linear expansion coefficient is in a range of 1/10 times to 10 times of a linear expansion coefficient of the silicon substrate 12, in the same way as the above-described support member 6.

[0032] The ink paths 18 are connected to the openings 16c of the above-described support members 16, and the other ends are connected to ink supply units 19a, 19b and 19c. The ink supply units 19a, 19b and 19c may be arbitrarily selected from a continuous supply pomp, a constant rate supply pomp and the like, according to the intended use of the fine pattern forming device 11. Although the only one ink path 18 is provided for each support member 16 in the example shown in the figure, a plurality of openings 16c may be provided on one support member 16 and the ink path 18 may be connected to each of the openings 16c, considering the uniformity of fluid pressure of the ink. Furthermore, the ink path may be formed inside the support member 16.

[0033] Such fine pattern forming device 11 of the invention can discharge ink in a small amount with high accuracy from the fine holes 13 of the silicon substrate 12. In addition, by supplying different kinds of ink from the ink supply units 19a, 19b and 19c, pattern formation by direct drawing with desired ink can be performed per each device part 11a, 11b and 11c. It is advantageous especially for forming a striped pattern by a forming method of the invention described later. Furthermore, since the device parts 11a, 11b and 11c are integrated to structure the fine pattern forming device 11, it is unnecessary to connect a plurality of devices, and the position accuracy of each device is extremely high. In addition, the amount of ink discharged can be set arbitrarily by changing the supplying amount by controlling the ink supply units 19a, 19b and 19c.

[0034] As for the fine pattern forming device 11 also, nozzles shown in Fig. 2 may be provided in a protruding condition on the openings 13b of the fine holes 13 on the silicon substrate 12 rear surface 12B side.

[0035] (Fourth embodiment mode) Fig. 5 shows another embodiment mode of a fine pattern forming device of the invention, and (A) is a schematic cross-sectional view, (B) is a bottom view. In Fig. 5, a fine pattern forming device 21 is provided with a silicon substrate 22, a support members 26 placed on a front surface 22A side of the silicon substrate 22, three ink paths 28a, 28b and 28c formed inside the silicon substrate 22 and the support member 26, and ink supply units 29a, 29b and 29c connected to each of the ink paths.

[0036] The silicon substrate 22 is provided with a plurality of fine holes 23 penetrating from the front surface 22A side to a rear surface 22B side, and openings 23a

on the front surface 22A side of the fine holes 23 are exposed to any of the three ink paths 28a, 28b and 28c formed like grooves on the front surface 22A side. A material of the silicon substrate 22 can be the same as the above-described silicon substrate 2, and the thickness can also be set in the same range as the silicon substrate 2.

[0037] A plurality of the fine holes 23 are placed on the same line along a predetermined direction (an arrow direction in Fig. 5 (B)) and a plurality of such lines are formed with a pitch P. In the example shown in the figure, six fine hole lines 23A, 23B, 23C, 23D, 23E and 23F on which a plurality of fine holes are aligned along the arrow direction are formed with the pitch P. The transverse section shape, longitudinal section shape, opening diameter and forming pitch of the fine holes 23 as these can be set arbitrarily, in the same way as the above-described fine holes 3. In addition, a silicon oxide layer 24 formed on the wall surface of the fine hole 23 can be the same as the above-described silicon oxide layer 4. In the example shown in the figure, the opening diameter, formation number, forming pitch and the like of the fine holes 23 provided with the silicon oxide layers 24 are simplified so that the description of the device structure becomes easier.

[0038] The support member 26 is a plate-like member placed on the front surface 22A side of the above-described silicon substrate 22, for holding the silicon substrate 22, and the ink paths 28c are formed like grooves on the silicon substrate 22 side of the support member 26.

[0039] Fig. 6 is a transverse sectional view at A-A line of the silicon substrate 22 shown in Fig. 5 (A), and Fig. 7 is a transverse sectional view at B-B line of the support member 26 shown in Fig. 5 (A).

[0040] As shown in Fig. 5 (A) and Fig. 6, the groove-like ink path 28a formed so that each opening of the fine hole lines 23A and 23D and the ink supply unit 29a are connected, and the groove-like ink path 28b formed so that each opening of the fine hole lines 23B and 23E and the ink supply unit 29b are connected are formed on the silicon substrate 22. In addition, the ink path 28c is formed over each opening of the fine hole lines 23C and 23F. Furthermore, as shown in Fig. 5(A) and Fig. 7, the groove-like ink path 28c formed so that each opening of the fine hole lines 23C and 23F and the ink supply unit 29c are connected is formed on the support member 26.

[0041] The three ink paths 28a, 28b and 28c formed between the support member 26 and the silicon substrate 22 as the above are independent of each other, as shown in Fig. 8. The material of the support member 26 is preferably a material whose linear expansion coefficient is in a range of 1/10 times to 10 times of a linear expansion coefficient of the silicon substrate 22, in the same way as the above-described support

member 6.

[0042] The ends of each ink path 28a, 28b and 28c described above are connected to the ink supply units 29a, 29b and 29c. The ink supply units 29a, 29b and 29c have no special limitation, and they may be any of a continuous supply pomp, a constant rate supply pomp and the like, selected arbitrarily according to the intended use of the fine pattern forming device 21.

[0043] Such fine pattern forming device 21 of the invention can discharge ink in a small amount with high accuracy from the fine holes 23 of the silicon substrate 22. In addition, by supplying different kinds of ink from the ink supply units 29a, 29b and 29c, pattern formation by direct drawing with desired ink can be performed per each of the fine hole lines divided into groups corresponding to each ink path 28a, 28b and 28c (a group of the fine hole lines 23A and 23D, a group of the fine hole lines 23B and 23E, and a group of the fine hole lines 23C and 23F). It is advantageous especially for forming a striped pattern by a forming method of the invention described later. Furthermore, since the fine pattern forming device 21 is not made by a plurality of connected devices per each ink, the position accuracy of each fine hole line is extremely high. In addition, the amount of ink discharged can be set arbitrarily by changing the supplying amount by controlling the ink supply units 29a, 29b and 29c.

[0044] As for the fine pattern forming device 21 also, nozzles shown in Fig. 2 may be provided in a protruding condition on the openings 23b of the fine holes 23 on the silicon substrate 22 rear surface 22B side.

[0045] (Fifth embodiment mode) Fig. 9 is a plain view showing another embodiment mode of a fine pattern forming device of the invention. In Fig. 9, a fine pattern forming device 31 is provided with a silicon substrate 32, a support member which is placed on a front surface 32A side of the silicon substrate 32, an ink path which supplies ink to a void part between the silicon substrate 32 and the support member, and an ink supply unit connected to the ink path. However, only the silicon substrate 32 is shown in Fig. 9, and the support member, the ink path and the ink supply unit are not shown.

[0046] The silicon substrate 32 is provided with a plurality of fine holes 33 which penetrate from the front surface 22A side to a rear surface side. The fine holes 33 are formed in a position so as to make a pattern 35, and a plurality of (10, in the example shown in the figure) patterns 35 are provided on the silicon substrate 32. The fine holes 33 are shown only in one of the patterns 35, and the other patterns 35 are shown only by the outline with a chained line.

[0047] A material of the silicon substrate 32 can be the same as the above-described

silicon substrate 2, and the thickness can also be set in the same range as the silicon substrate 2. In addition, the transverse section shape, longitudinal section shape, opening diameter and forming pitch of the fine holes 33 can be set arbitrarily, in the same way as the above-described fine holes 3. Furthermore, the fine hole 33 may be provided with a silicon oxide layer on the wall surface, and the silicon oxide layer can be the same as the above-described silicon oxide layer 4.

[0048] As for the silicon substrate 32 as this, by using a support member having a flange part on the periphery as the above-described support member 6, the flange part of the support member can be bonded to the peripheral part (a region shown by diagonal lines). And, an ink supply path is connected to an opening of the support member, and an ink supply unit can be connected to the other end of the ink supply path.

[0049] The fine pattern forming device 31 as this can form a pattern with the shape corresponding to the pattern 35 stably with high accuracy on a substance on which the pattern is formed, by direct drawing, discharging a moderate amount (the amount with which the ink discharged from adjacent fine holes 33 has contacts) of ink from the fine holes 33 of the silicon substrate 32. The amount of ink discharged can be adjusted by controlling the ink supply unit.

[0050] Although the plurality of patterns 35 have all the same shape in the above-described example, they can have arbitrary shapes such as a conductor pattern of a printed-wiring board, for example, without limited to this.

[0051] As for the fine pattern forming device 31 also, nozzles shown in Fig. 2 may be provided in a protruding condition on the openings of the fine holes 33 on the silicon substrate 32 rear surface side.

[0052] Manufacturing Example of Fine Pattern Forming Device

Next, manufacture of a fine pattern forming device of the invention will be described, taking the fine pattern forming device 1' shown in Fig. 2 as an example, referring to Fig. 10 and Fig. 11.

[0053] First, by oxidizing a silicon substrate 2 whose surface is cleaned in a thermal oxidation furnace, a silicon oxide film 2' with a thickness of approximately 1 to 2 μm is formed all over the surface. (Fig. 10 (A))

[0054] Next, a photosensitive resist is applied to one of the surfaces of the silicon substrate 2, and a resist pattern R is formed by exposure through a predetermined photomask and development. (Fig. 10 (B)) After that, using the resist pattern R as a mask, the silicon oxide film 2' is patterned by using BHF16 (ammonium bifluoride 22% solution), for example. (Fig. 10 (C)) This patterning may be performed by dry etching using RIE (Reactive Ion Etching) (process gas: CHF_3). By such patterning, the

silicon oxide film 2' in the part where the resist pattern R is not provided is removed.

[0055] Next, using the patterned silicon oxide film 2' as a mask, fine holes 3 are perforated with a predetermined depth on the silicon substrate 2. (Fig. 10 (D)) Perforating of the fine holes 3 can be performed by high aspect etching such as ICP-RIE (Inductively Coupled Plasma ? Reactive Ion Etching) etching, wet etching and Deep RIE etching, for example. Perforating of the fine holes 3 are performed to a predetermined depth not penetrating the silicon substrate 2.

[0056] Next, the resist pattern R and the silicon oxide film 2' are removed, and after that, a silicon oxide layer 4 with a thickness of approximately 5000 to 10000 Å is formed all over the surface by oxidizing in the thermal oxidation furnace. (Fig. 10 (E))

[0057] Next, a flange part 6b of a support member 6 is bonded to a peripheral part of the front surface side (the side on which the fine holes are perforated) of the silicon substrate 2. (Fig. 11 (A)) This bonding can be performed by anodic bonding, for example.

[0058] After that, only the external side of the silicon substrate 2 is dipped in BHF16 so that the silicon oxide layer 4 in this part is removed and the rear surface of the silicon substrate 2 is exposed. After that, etching is performed from the rear surface side of the silicon substrate 2 by TMAH (tetramethylammonium hydroxide). (Fig. 11 (B)) By this etching, fine pipes formed of the silicon oxide layer 4 protrude to the silicon substrate 2 side, since the silicon oxide layer 4 formed on the inner wall of fine holes 3 is resistant to TMAH.

[0059] After that, the tips of the fine tubes formed of the silicon oxide layer 4 are removed by dissolving using BHF16, and opened. (Fig. 11 (C)) After that, the rear surface side of the silicon substrate 2 is etched again by TMAH. And, when nozzles 5 formed of the silicon oxide layer 4 with a predetermined length are formed, etching by TMAH is stopped. (Fig. 11 (D)) After that, an ink supply unit is connected to an opening 6c of the support member 6 through an ink path, so that the fine pattern forming device 1' of the invention shown in Fig. 2 can be manufactured.

[0060] The above-described etching of the rear surface side of the silicon substrate 2 may be performed by dry process using RIE (Reactive Ion Etching), besides using TMAH.

[0061] In addition, a fine pattern forming device 1 shown in Fig. 1 can be manufactured by perforating fine holes 3 so as to penetrate a silicon substrate 2 in a process corresponding to Fig. 10 (D), or by removing fine tubes formed of a protruding silicon oxide layer 4 by dissolving using hydrofluoric acid in a process corresponding to Fig. 11 (C).

[0062] Fine Pattern Forming Method of the Invention
(First embodiment mode) Fig. 12 is a diagram to describe an embodiment mode of a fine pattern forming method of the invention using the above-described fine pattern forming device 11 of the invention. In Fig. 12, a substance S on which a pattern is formed is scanned in a predetermined direction (an arrow A direction) with respect to the fine pattern forming device 11, while supplying ink A, ink B and ink C from ink supply units 19a, 19b and 19c of the fine pattern forming device 11 of the invention respectively through each ink path 18. The scanning direction A corresponds with an alignment direction A of fine holes (refer to Fig. 4) in the above-described fine pattern forming device 11. In this case, a space between a silicon substrate 12 of the fine pattern forming device 11 and the substance S on which a pattern is formed can be set in a range of approximately 0.1 to 5 mm.

[0063] In this way, by the ink discharged from the fine holes 13 of the silicon substrate 12, a striped pattern in which the ink A, ink B and ink C are aligned repeatedly in this order is formed on the substance S on which a pattern is formed by direct drawing. The pitch of each stripe in this case is P2. As for this striped pattern, one stripe is formed by the ink discharged from a plurality of fine holes on the same line. Therefore, even when the amount of ink discharged from each fine hole is small, the scanning speed of the substance S on which a pattern is formed can be increased so that the pattern-forming speed is increased. The striped pattern as this is formed with extremely high accuracy, corresponding to the diameter of the fine holes 13, and the process is simpler than a conventional photolithography.

[0064] In the case where a substance S on which a pattern is formed has flexibility as a resin film, it is preferable that a backup roller is placed on the rear surface of the substance S on which a pattern is formed so as to oppose to a fine pattern forming device 11 and direct drawing is performed carrying the substance S on which a pattern is formed while applying tension.

[0065] (Second embodiment mode) Fig. 13 is a diagram to describe another embodiment of a fine pattern forming method of the invention, and it is an example in which the fine pattern forming device 31 of the invention is used. In Fig. 13, the fine pattern forming device 31 (only the silicon substrate 32 is shown in the figure) is placed in a predetermined position of a substance S on which a pattern is formed, and a pattern is formed by discharging a certain amount of ink supplied from the ink path through each fine hole 33 on the substance on which the pattern is formed. After that, the substance S on which the pattern is formed is carried a predetermined distance in an arrow A direction, and the same pattern formation is performed. By repetition of such

operations, a desired pattern 35 is formed on the substance S on which a pattern is formed. The space between the silicon substrate 32 of the fine pattern forming device 31 and the substance S on which a pattern is formed can be set in a range of approximately 0.1 to 5 mm.

[0066] Furthermore, a printed-wiring board can be manufactured easily, not using photolithography, by using a conductor paste as ink, setting the pattern 35 structured by a plurality of fine holes 33 in the fine pattern forming device 31 as a conductor pattern of a printed-wiring board, for example.

[0067]

[Embodiment] Next, the invention will be described in further detail, showing an embodiment.

[0068] [Manufacture of Fine Pattern Forming Device] A silicon substrate (diameter 3 inches, thickness 200 μm, one-side polished, crystal orientation <100>, linear expansion coefficient = 2.6×10^{-6}/K) whose surface is RCA-cleaned is prepared. By oxidizing this silicon substrate in a thermal oxidation furnace under the following condition, a silicon oxide film with a thickness of approximately 2 μm is formed all over the surface.

[0069] (Condition of thermal oxidation)

heating temperature: 1050 °C

amount of hydrogen gas supplied: 1s1m

amount of oxygen gas supplied: 1s1m

heating time: approximately 15 hours

[0070] Next, a photosensitive resist (Micro Posit manufactured by Shipley Company L.L.C) is applied on the polished surface side by spin-coating and dried, and after that, a resist pattern is formed by exposure through a predetermined photomask and development. On the resist pattern, circular openings (diameter 10 μm) are formed on one line in an x-axis direction with 20 μm pitch, and the opening lines are aligned in a y-axis direction with 20 μm pitch. After that, using the resist pattern as a mask, the silicon oxide film is patterned by BHF16 (ammonium bifluoride 22% solution), and the silicon oxide film in the part where the resist pattern is not provided is removed by dissolving.

[0071] Next, using the patterned silicon oxide film as a mask, high aspect etching is performed by ICP-RIE (Inductively Coupled Plasma ? Reactive Ion Etching) is performed, so that fine holes with a diameter of 10 μm and a depth of 200 μm are perforated. After that, the resist pattern is removed by using a mixed solution of sulfuric acid and hydrogen peroxide water, and the mask of the silicon oxide film is

removed using hydrofluoric acid.

[0072] After that, by performing an oxidation treatment in the thermal oxidation furnace under the same condition as the above, except that the heating time is set to be approximately three hours, to the silicon substrate on which the fine holes are perforated as described above, a silicon oxide layer with a thickness of approximately 5000 Å is formed all over the surface. By this oxidation treatment, the silicon oxide layer is formed on the wall surfaces of the fine holes also.

[0073] Next, a support member made of pyrex glass (trade name Corning #7740, linear expansion coefficient = 3.5×10^{-6}/K, diameter 3 inches) on which a flange part and an opening are formed is bonded to a peripheral part of the front surface side (the side on which fine holes are perforated) of the silicon substrate by anodic bonding (temperature 500 °C, applied voltage approximately 750 V, applying time 10 minutes).

[0074] After that, only the external side of the silicon substrate is dipped in BHF16 so that the silicon oxide layer is removed and the rear surface of the silicon substrate is exposed. After that, the rear surface side of the silicon substrate is dipped in TMAH (tetramethylammonium hydroxide) and etching is performed. By this, on the rear surface of the silicon substrate, there are fine tubes made of the silicon oxide layer formed on the wall surfaces of the fine holes by the above-described oxidation treatment, protruding approximately 5 μm

[0075] After that, the tips of the fine tubes formed of the silicon oxide layer are dipped in BHF16 and removed by dissolving, so that they are opened. After that, the rear surface side of the silicon substrate is etched by TMAH, and nozzles with a length of 10 μm are formed.

[0076] Next, an ink path of a resin pipe is connected to the opening of the support member, and the other end of the resin pipe is connected to an ink supply unit (1500XL manufactured by EFD Inc.). By this, the fine pattern forming device of the invention is obtained.

[0077] [Formation of Fine Pattern] The ink supply unit is filled up by ink (color mosaic CR-7001 manufactured by Fujifilm Olin Co., Ltd.), and a glass substrate (100 mm × 100 mm) is prepared as a substance on which a pattern is formed.

[0078] Next, while scanning the glass substrate at a constant speed of 50 mm/sec. in an x-axis direction of the above-described fine pattern forming device, ink is supplied from the ink supply unit to the silicon substrate, and the ink is discharged from the fine holes so that a striped pattern is drawn, then dried. Each stripe of the obtained pattern is extremely highly accurate, with a line width of 25±1 μm, and a line pitch of 25±1 μm.

[0079]

[Effect of the Invention] As described in detail above, according to the invention, the fine pattern forming device can discharge a small amount of ink from fine holes of the silicon substrate with high accuracy, and the discharging amount can be set arbitrarily by changing the amount of ink supply. Furthermore, highly accurate pattern formation can be performed easily and stably, by drawing directly attaching ink on a substance on which the pattern is formed. In addition, with the pattern forming method in which the fine pattern forming device of the invention and the substance on which the pattern is formed are scanned relatively, a striped pattern can be formed with high accuracy, and by discharging ink from a plurality of fine holes aligned on the same line along the scanning direction, the pattern forming speed can be increased even when the amount of ink discharged from one fine hole is small. Furthermore, with the pattern forming method in which the fine pattern forming device of the invention is set aligned in a predetermined position of the substance on which the pattern is formed and a certain amount of ink is discharged from each fine hole, a desired pattern can be easily formed repeatedly with high accuracy, and it can be applied to formation of a color filter in a matrix, a conductor pattern of a printed-wiring board or the like.

[Brief Description of the Drawings]

Fig. 1 is a schematic cross-sectional view showing an embodiment of a fine pattern forming device of the invention.

Fig. 2 is a schematic cross-sectional view showing another embodiment of a fine pattern forming device of the invention.

Fig. 3 is a schematic cross-sectional view showing another embodiment of a fine pattern forming device of the invention.

Fig. 4 is a bottom view of the fine pattern forming device shown in Fig. 3.

Fig. 5 shows another embodiment of a fine pattern forming device of the invention, and (A) is a schematic cross-sectional view, (B) is a bottom view.

Fig. 6 is a transverse sectional view at A-A line of the support member of the fine pattern forming device shown in Fig. 5.

Fig. 7 is a transverse sectional view at B-B line of the support member of the fine pattern forming device shown in Fig. 5.

Fig. 8 is a perspective view showing the ink path of the fine pattern forming device shown in Fig. 5.

Fig. 9 is a schematic cross-sectional view showing another embodiment of a fine pattern forming device of the invention.

Fig. 10 is a process chart showing a manufacturing example of a fine pattern forming device of the invention.

Fig. 11 is a process chart showing a manufacturing example of a fine pattern forming device of the invention.

Fig. 12 is a perspective view showing an embodiment of a fine pattern forming method of the invention.

Fig. 13 is a perspective view showing another embodiment of a fine pattern forming method of the invention.

[Description of Symbols]

1, 1', 11, 21 and 31: fine pattern forming device

2, 12, 22 and 32: silicon substrate

3, 13, 23 and 33: fine hole

3a, 13a and 23a: opening

3b, 13b and 23b: opening

4, 14 and 24: silicon oxide layer

5: nozzle

6, 16 and 26: holding member

8, 18 and 28: ink path

9, 19a, 19b, 19c, 29a, 29b and 29c: ink supply unit

S: substance on which a pattern is formed

Continued from the front page

F term (reference): 2C057, AF01, AG04, AG05, AG07, AG12
AG14, AG16, AH05, AJ10, AN01
AP13, AP28, AP32, AP33, AP56
AQ02, BF06
2H088, EA67, FA30, HA01, HA02, MA20
5E343, AA26, BB72, DD15, FF02, GG11